Mass Hierarchy of Collisional Energy Loss

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Outline

Hard Probes in Relativistic Heavy Ion Collisions

- A snapshot of medium created in a collision
  - We know how high p_t partons are produced (we think so)
  - Those partons hadronize outside the medium created

  $\Rightarrow$ We make conclusions on what happens between creation and hadronization

Partons loose energy

- Energy loss is sensitive to medium properties
  - Radiative energy loss – parameterized by $\hat{q} \propto$ density (Escola et al. '04, Armesto et al. '05)
  - Collisional energy loss – not so definite...

    (*a*) massless partons, thermal motion (Djordjevic'06)

    (*b*) massive scatterers at rest, mass taken to fit dE/dx of (*a*) (Gyulassy, Wicks '07).

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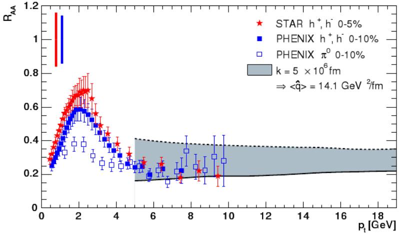
Highlights on Radiative Energy Loss

Radiative E-loss:

- Fairly explains data on light hadron supression at RHIC (Dainese, Loizides'05)



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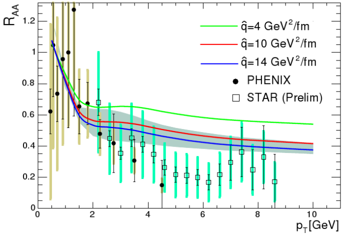

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Can collisional (elastic) energy loss change the situation?

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Collisional Energy Loss on a Classical Level

Let us consider elastic collision of two non-relativistic balls…

$m_p \ll m_t$		$\approx$ No loss
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$m_p \approx m_t$		Significant loss!

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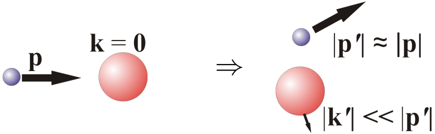
$m_p \ll m_t$		$\approx$ No loss
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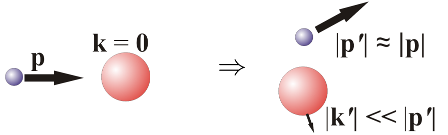
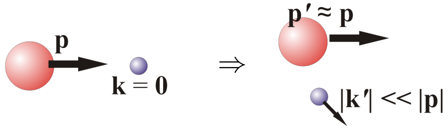
$m_p \ll m_t$		$\approx$ No loss
$m_p \gg m_t$		$\approx$ No loss
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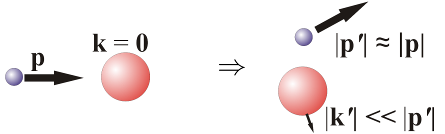
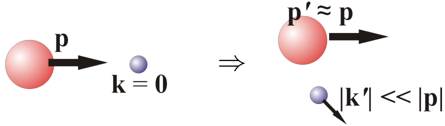
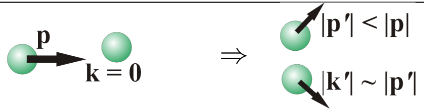
$m_p \ll m_t$		≈ No loss
$m_p \gg m_t$		≈ No loss
$m_p \approx m_t$		Significant loss!

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Collisional Energy Loss on a Classical Level

Energy loss due to elastic collisions could have mass hierarchy different from the radiative depending on what (parton effective mass) we take for the medium!

NB: Arguments above are based solely on conservation laws, thus should be valid irrespective of the scattering matrix element. (Provided projectile parton is not too relativistic)

The Model

We take medium as a set of independent scattering centers in thermal motion.
Number of collisions per unit time:

$$\frac{dN_{pi}}{dt} = \int d^3\mathbf{k} n_i(\mathbf{k}) \frac{|\mathcal{M}_{pi}(p,q,k)|^2 \delta(p+k-p_f-k_f)}{2k^0 2p^0 (2\pi)^2} \frac{d^3k_f}{2k_f^0} \frac{d^3p_f}{2p_f^0}$$

Energy loss per unit path:

$$\frac{dE}{dx} = \frac{dN^{tot}}{dt} \langle \Delta E \rangle_1 \frac{1}{dx/dt} = \frac{E}{p} \frac{dN}{dt} \langle \Delta E \rangle_1$$

Definition: $\dfrac{d\sigma^{\mathrm{int}}}{dp_f} = 2\pi \int d\cos\psi \dfrac{1}{4p^0 k^0} |\mathcal{M}|^2 d\Phi$

Calculation Details and Parameters

$$\frac{dE_Q}{dx} = \frac{1}{v_Q}\int dp_f(E_0 - E_f)\int k^2 dk\left(n_q(k)\frac{d\sigma^{\rm int}_{Qq}(k)}{dp_f} + n_g(k)\frac{d\sigma^{\rm int}_{Qg}(k)}{dp_f}\right)$$

$$\approx \frac{1}{v_Q}\int dp_f(p - p_f)\int k^2 dk(n_q(k) + \frac{9}{4}n_g(k))\frac{d\sigma^{\rm int}_{Qq}(k)}{dp_f}$$

where $n_q(k)$ and $n_g(k)$ – thermal momentum distributions (Fermi and Bose respectively).

- We take HTL-regularized propagator (Braaten '91, Kalashnikov, Klimov '79) for $|\mathcal{M}|^2$
- We keep all the mass dependence both in $|\mathcal{M}|^2$ and phase space
- Perform calculations for $T = 225$ MeV with *light* ($m_p = 200$ MeV), c ($m_p = 1200$ MeV) and b ($m_p = 4750$ MeV) quarks and target parton mass $m_t = 200$ MeV $- 1$ GeV

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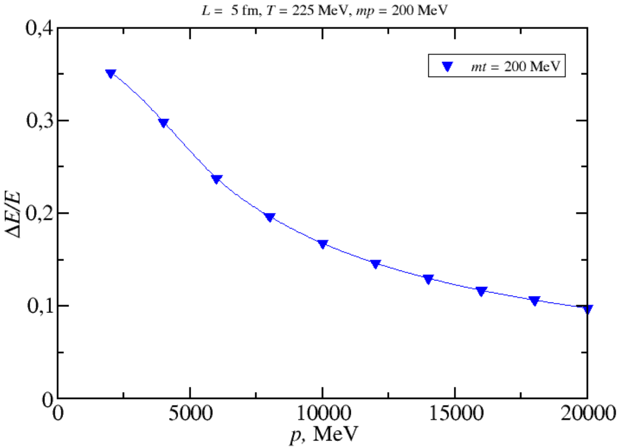
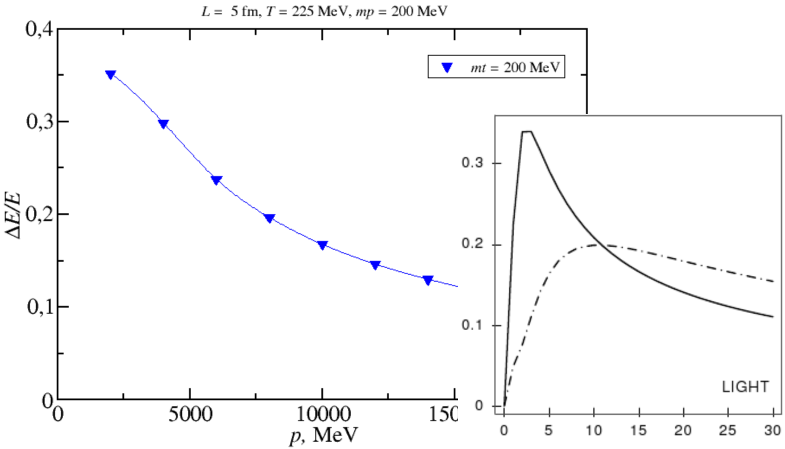
Light Quark



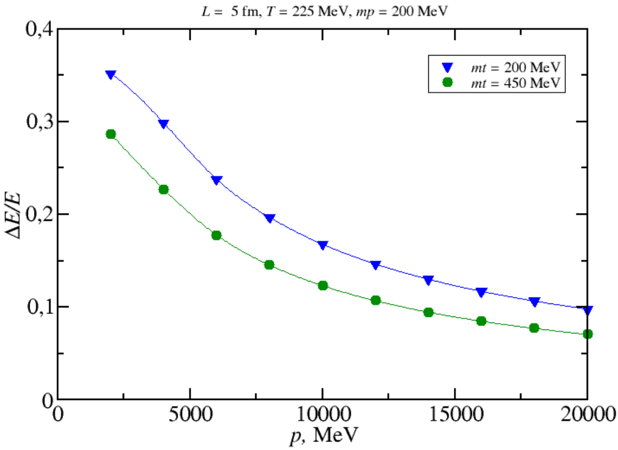
Energy loss for $m_t = 200$ MeV is consistent with other authors. . .

Light Quark



Djordjevic ’06, massless partons in the medium

Light Quark


L = 5 fm, T = 225 MeV, mp = 200 MeV
mt = 200 MeV
mt = 450 MeV
ΔE/E
p, MeV
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0,1
0,2
0,3
0,4
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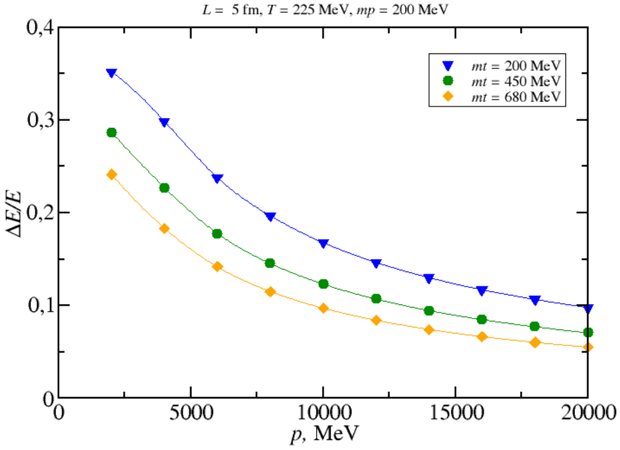
10000
15000
20000

Light Quark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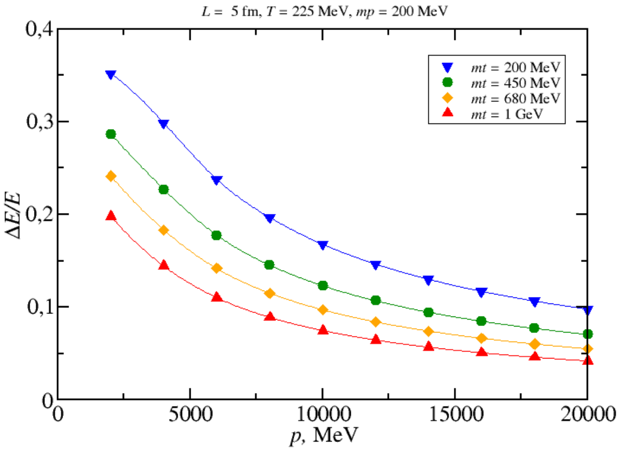
mt = 200 MeV
mt = 450 MeV
mt = 680 MeV

Light Quark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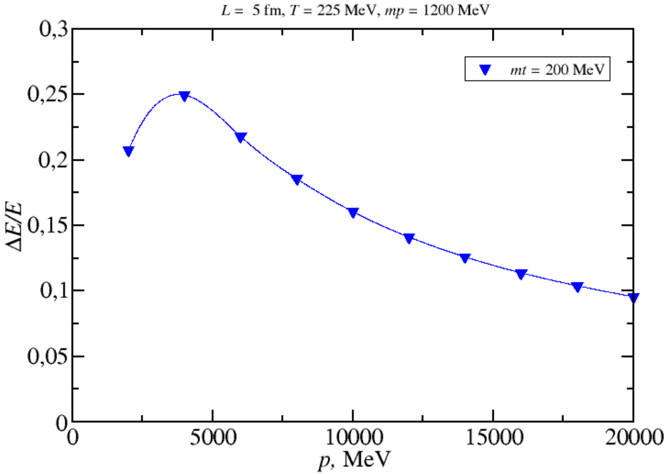
Charm Quark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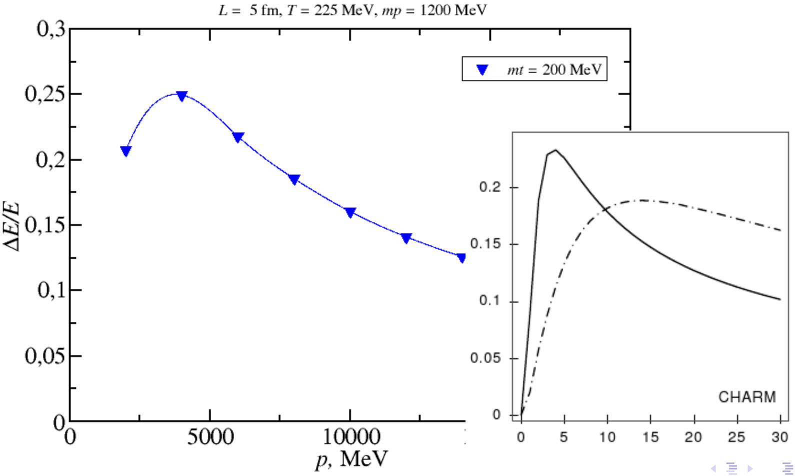
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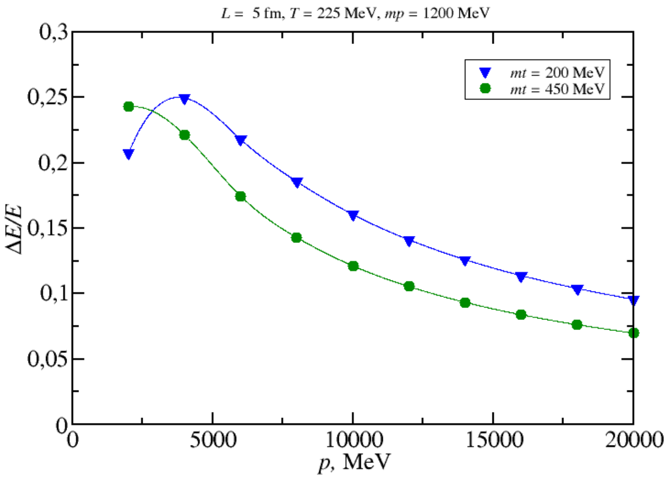
Charm Quark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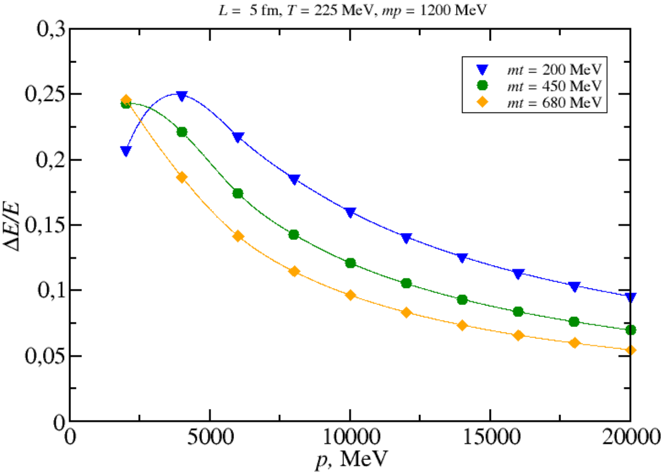
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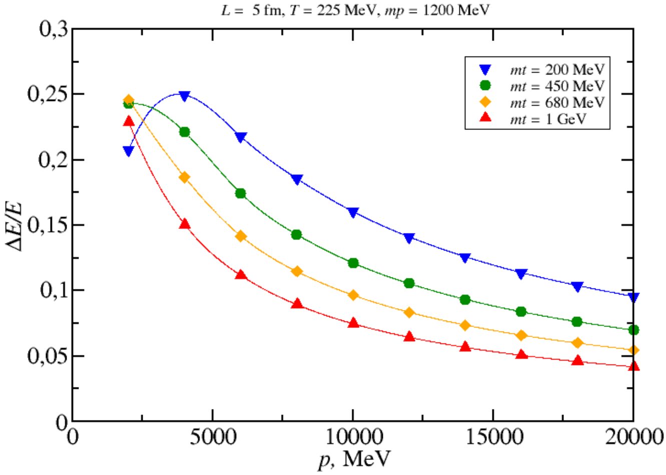
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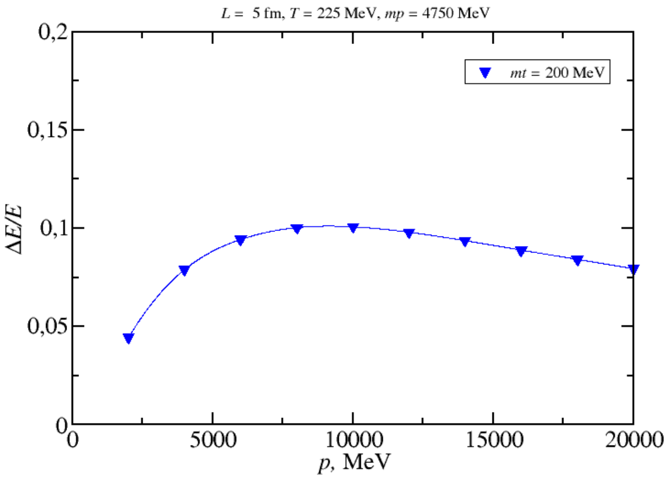

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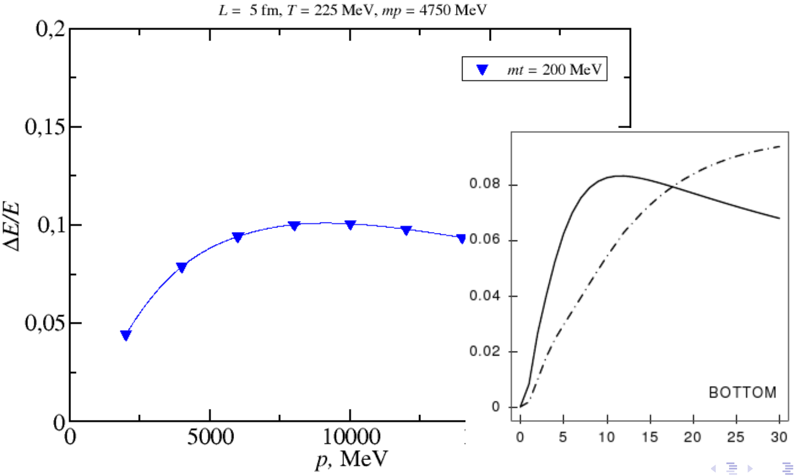

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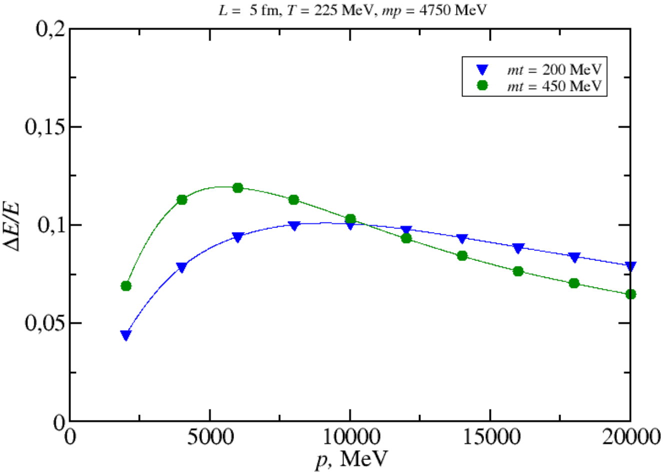

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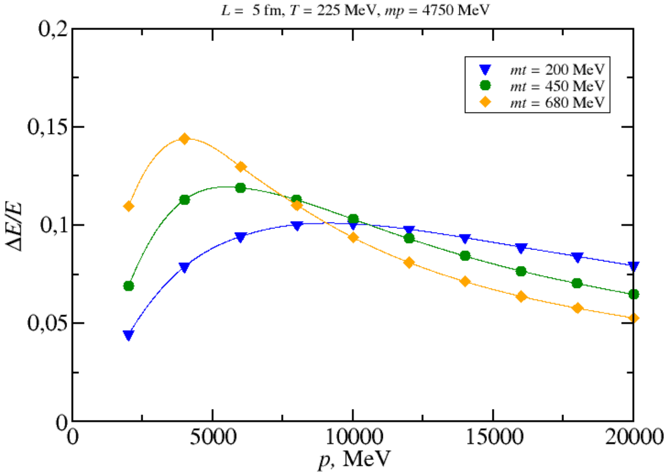

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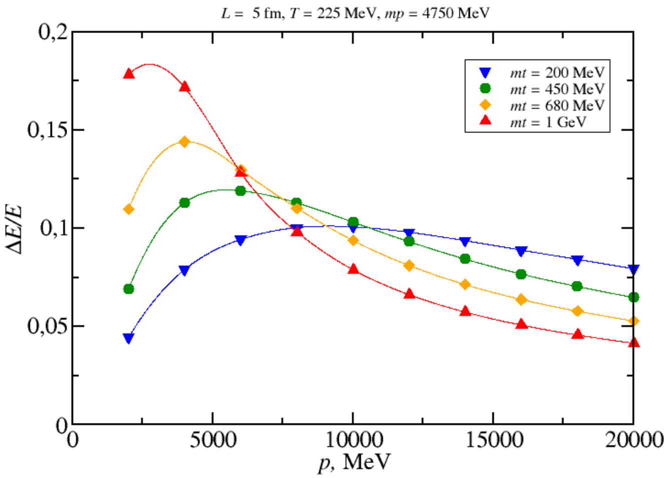
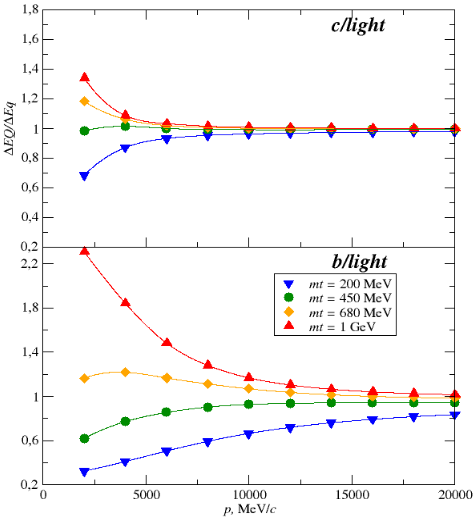


Variation of Mass Hierarchy



Mass hierarchy for collisional E-loss can be inverted by appropriate medium partom mass

Combining With Radiative Energy Loss

Ratios of absolute values of E-loss

- We assume that collisional and radiative energy loss add incoherently
- For instance we take radiative $\Delta E_{\rm rad}$ using ADSW'05 quenching weights with $\hat{q} = 1$ GeV^2/fm and $L = 5$ fm.

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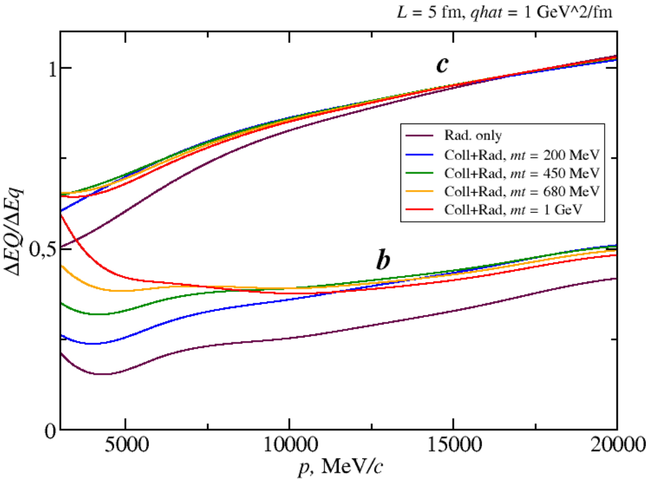

Summary

- Collisional energy loss is sensitive to the model we take for the medium, strongly depends on medium partons' mass
- Its mass hierarchy at intermediate energies can be varied with this parameter.
- Collisional E-loss effectively reduces mass hierarchy set by the radiative.

- Outlook
  - What should be taken for m_t?
  - Application to single electon supression in AA still to follow.